Design of Monopole Microstrip Patch Antenna for Ultra Wide Band Applications

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***Abstract*— A new monopole microstrip patch antenna design for ultra-wideband applications are proposed in this paper. The proposed antenna is comprised of a ring-shaped with additional slot and upper cutting edge, a 50-ohm microstrip line-fed and a slotted limited ground plane. The measurements of the proposed antenna be 3.5 cm × 2.4 cm × 0.16 cm and is energized by microstrip feed line. The Computer Simulation Technology (CST) and High Frequency Structural Simulator (HFSS) is applied in this analysis. The calculated bandwidth of the monopole antenna cover UWB frequency range. The proposed antenna has excellent gain. However, the measured results demonstrate that stable omnidirectional radiation patterns within the entire frequency band.**

***Index Terms*— Microstrip feed line, Printed monopole antenna, Ring-shaped, Ultra Wide Band.**

I. Introduction

Planar patch antenna is widely used in ultra wide band (UWB) applications and is continuing to fulfil the alternating demands of fast antenna technology. The community of wireless industry and the academic society are searching UWB technology to deliver the batter performance, especially after the US Federal Communication (FCC) approved in order to commercial communication purposes an unlicensed frequency band namely UWB. The range of the frequency band is 3.1 to 10.6 GHz [1]. Application of wideband based efficient size small antenna is still challenging to design. The impedance bandwidth of the UWB application to be at least fifty percent to cover the lower band of 3.1 to 5 GHz or 6 to 10.6 GHz upper band, or 110% covering the full UWB band of 3.1 to 10.6 GHz. The working band would be linear to reduce pulse distortions and phase variation. Planar microstrip patch antenna are commonly used in the latest wireless communication systems because of their attractive features namely simple structural design, compact size, low profile, low weight, constant gain, stable radiation patterns, and easy to manufacture[2,3]. Due to the attractive characteristics, microstrip line-fed antenna are widely used in appearing UWB applications, and day by day research movement is increased to focus on them.

A microstrip line-fed compact antenna with square patch and rectangular ground plane was published. The measured range of impedance band width was 3.1-10.60 GHz with a notch 3.1-8.06 GHz. However, this monopole antenna is superior with respect to the proposed design according to dimension and impedance band width, it had a stop band 3.1-8.06 GHz, and therefore, entire UWB is not covered. Thus, useful information of 3.1-8.06 GHz band will be lost due to notch and received information will be degraded and, therefore coverage range and signal quality will be low, as in [4]. A small elliptical ring antenna of UWB application with coplanar waveguide was investigated by Ren et al. To enlarge the span of the major axis of elliptical ring, wideband performance was achieved by this antenna and 4.6-10.3 GHz bandwidth was illustrated. The entire UWB was not covered by this antenna in spite of compact sizes [5]. A printed circular planar monopole antenna of novel design was proposed with dimension of 42 mm × 50 mm .On the other hand, the demand of UWB with a working band width range from 2.78 to 9.78 GHz was not fulfill by the antenna [4]. For UWB application, the small size of crescent planar antenna was proposed. The dimension of the antenna was 45 mm×50 mm that did not cover the UWB upper frequency [7]. A wideband compact UWB antenna is designed to take licensed UWB frequency band with notch, but full UWB frequency band has not been covered in [8]. A microstrip printed planate monopole antenna was published for UWB implementations. The antenna was cover from 2.6 to 12.3 GHz impedance bandwidth but the dimension of the antenna had relatively big in [9].

II. GEOMETRY OF UWB ANTENNA

The width and length of the printed monopole antenna can be measured from (1) and (2) narrated in [10], where W be the width and L be the length of printed monopole antenna, εr be the dielectric constant of FR4 substrate, f_0 be the target centre frequency, and εe be the effective dielectric constant, c be the light velocity.

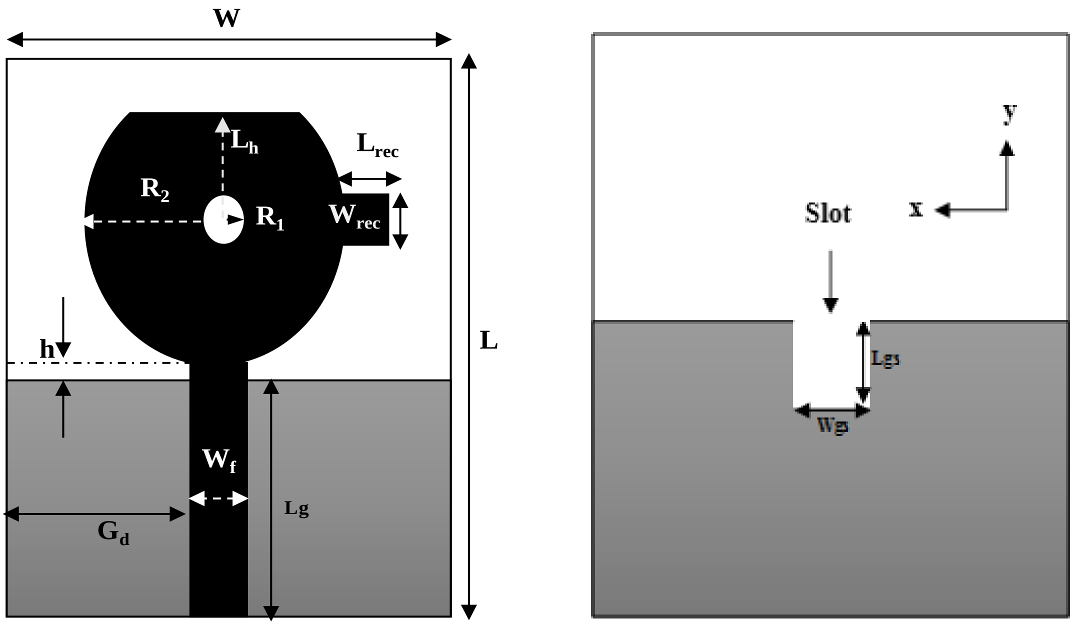
Now,

$$W = \frac{c}{2\,f_0}\sqrt{\frac{\varepsilon_r + 1}{2}}, \tag{1}$$

$$L = \frac{c}{2\,f_0\sqrt{\varepsilon_r}} - 2\Delta l \tag{2}$$

The sketch of the proposed patch antenna is as illustrate in Fig. 1. The antenna comprises of a ring-shaped patch with additional rectangular components and a limited ground plane with a 0.3 cm × 0.25 cm slot on the upper side. The design has been implemented with the emitting patch on the substrate, a feed line and ground plane.

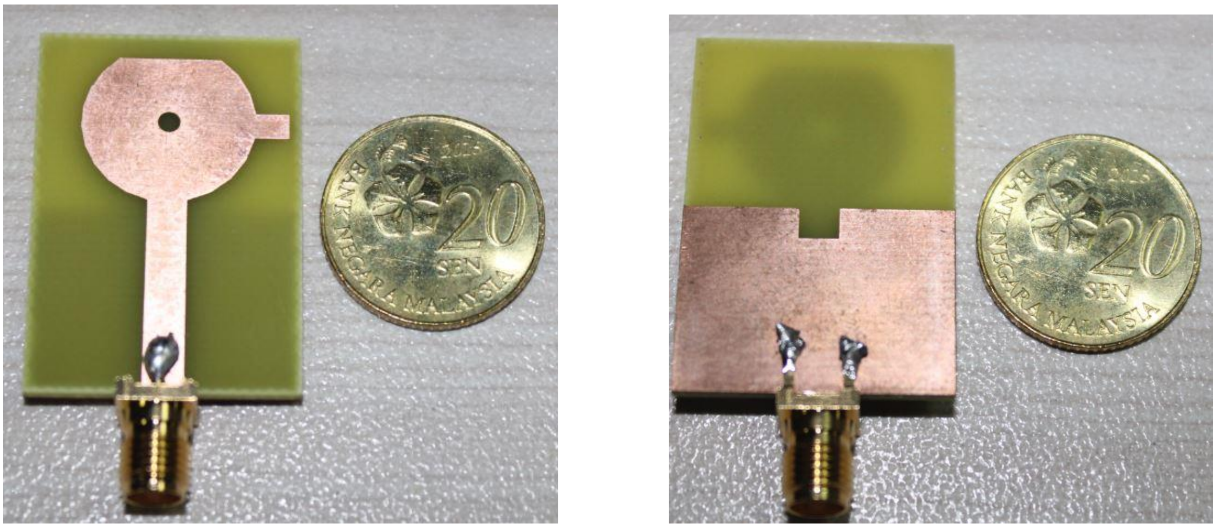
The proposed antenna has a compact dimension of 3.5 cm × 2.4 cm that is marked on one surface of an FR4 substrate which has thickness of 0.16 cm and a relative permittivity of 4.4, and loss tangent of 0.02. As emitter, a microstrip feed line of length, lf and width, wf is marked on the same side of the substrate. On the other side of the substrate, a limited ground plane with side length Lg is printed. The size of top slot on the limited ground plane is selected to be Wgs × Lgs and it is centre of the ground plane. A sub miniature version A (SMA) connector is attached to the 50-Ω microstrip supply line.



(a) Front Side (b) Back Side

Fig. 1 Geometry of the proposed monopole microstrip patch antenna

Finally, the optimized parameters that have been determined as follows: W = 2.4 cm, L = 3.5 cm, Lg = 1.75 cm, R_1 = 0.1cm, R_2 = 0.8 cm, h = 0.05 cm, G_d = 1.02 cm, w_f = 0.32 cm, W_{rec} = 0.25 cm, L_{rec} = 0.3 cm, L_h = 0.65 cm. The design numerical of the proposed patch antenna shape can be calibrated to verify the VSWR and the impedance bandwidth covering a band of frequencies. To support numerous resonant modes issuing a broad impedance bandwidth, the ring-shaped printed monopole antenna is capable



(a) Front Side (b) Back Side

Fig. 2 Photograph of the implemented antenna

III. EXPERIMENTAL AND SIMULATION RESULTS AND DISCUSSION

The capability of the proposed printed antenna was verified and optimized by technically available Technology such as CST & HFSS simulator. The patch antenna was fabricated on printed circuit board for practical observation, as illustrate in Fig. 2. The Satimo Starlab anechoic chamber of 0.6-18 GHz used in this experiment which was conducted by the microwave laboratory, at the institute of Space Science Centre (ANGKAS), UKM, Malaysia. Measuring the input impedance characteristics of the patch antenna, vector network of an Agilent E8362C analyser was utilized. The peak gain, radiation pattern, and total efficiency of the antenna was measured in Satimo Starlab. The near-field measurement techniques were used in this system. This technique allows computation of electric fields within the antenna's near-field to calculate the equivalent fare-field data of the antenna under test. The area of the antenna which occur effects on the electromagnetic induction and the electric charge. If distance increase from the antenna, near-field effects fade out far more quickly. The antenna mounted in the centre of an annular arch that comprises sixteen individual computation probes. Along the circular direction, probes are positioned equally apart. The antenna is revolved parallel to the plane of the horizon through full circle and carried out a full 3D scan of the antenna. After that it measured, plotted and analysed the 3D radiation patterns. Using far-field radiation pattern, efficiency, and antenna gain can be measured. Measuring system used a coaxial cable and firstly calibrated the system.

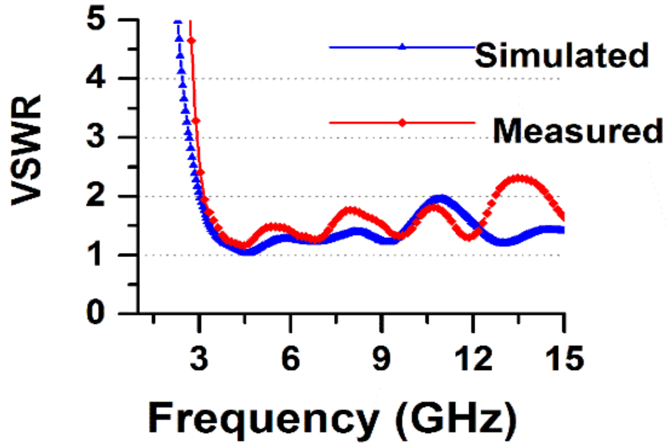


Fig. 3 Simulated and Measured results VSWR of proposed antenna

Fig. 3 illustrates the curve of the VSWR of the proposed monopole antenna which indicates the frequency range from 3.088 to 12.497GHz is the calculated impedance bandwidth below or equal 2. The measured results are similar with simulation results. The result may show little bit discrepancy between measurement and simulation due to fabrication errors. Moreover, because of the effect of microstrip feeding cable which is utilized in the measurement, discrepancy may be occurred. On the other hand, the discrepancy is not allowed in simulation.

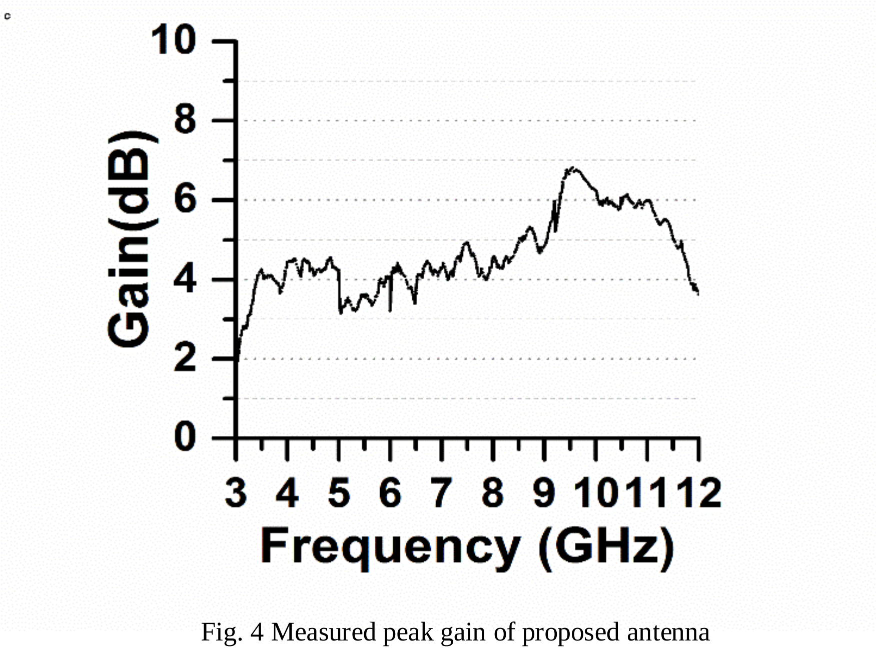


Fig. 4 Measured peak gain of proposed antenna

In spite of small dimension of proposed antenna, it can adjust over a wide band width that covering the full range from 3.1 to 10.6 GHz that is allocated for UWB application. Fig. 4 illustrates the measured peak gain of 3 to 12 GHz frequency range of the printed patch antenna. It can be observed from the figure that 4.2 dBi achieved at the first resonance for 4.5 GHz and 6.8 dBi at the second resonance 9.5 GHz. Moreover, the gain for the under band is less than for the above band.

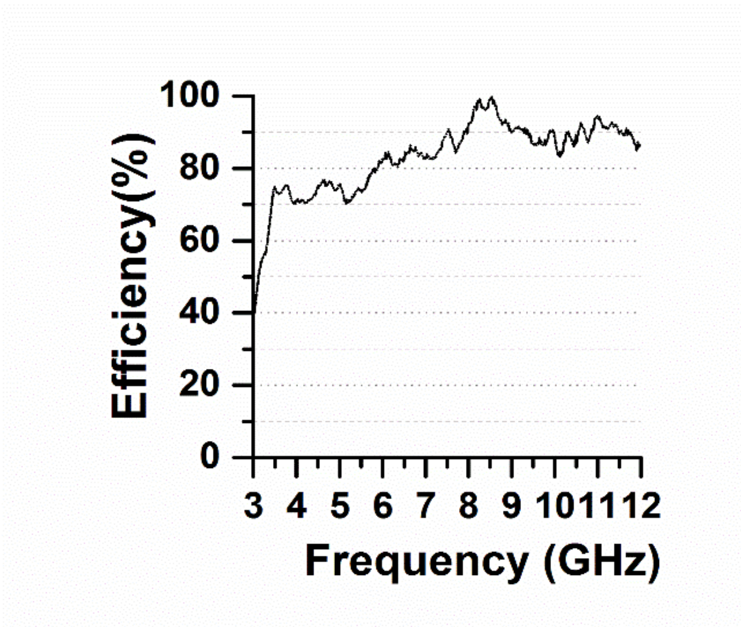
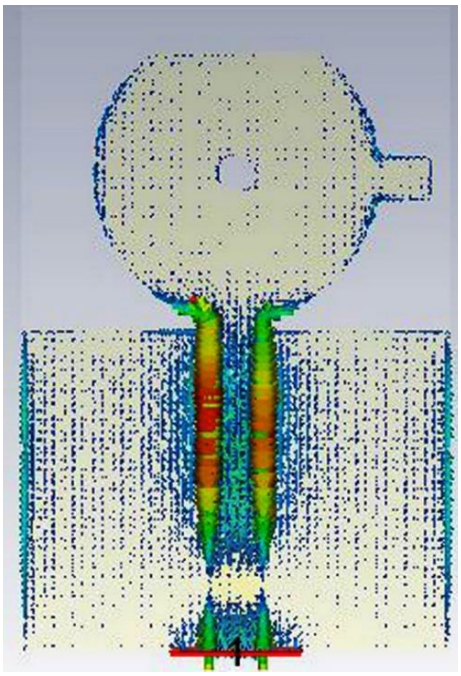
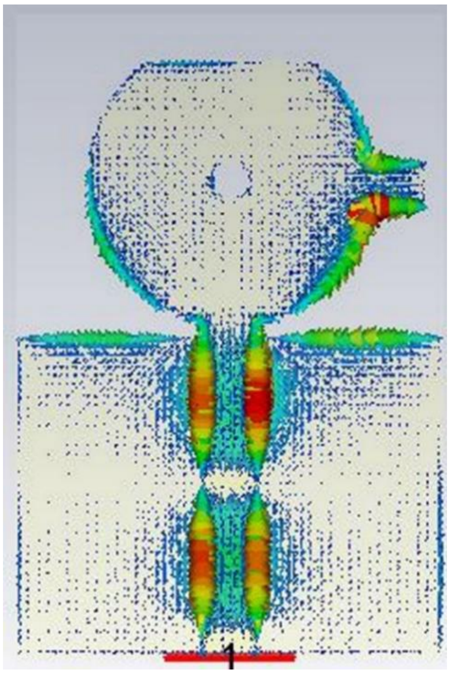


Fig. 5 Measured efficiency of proposed antenna

We have measured the gain and efficiency of monopole patch antenna using a Satimo Starlab near-field measurement system. Fig. 5 has demonstrated the radiation efficiency of lower band 70.11% and whereas 82.22% is the efficiency of the higher band.



(a)

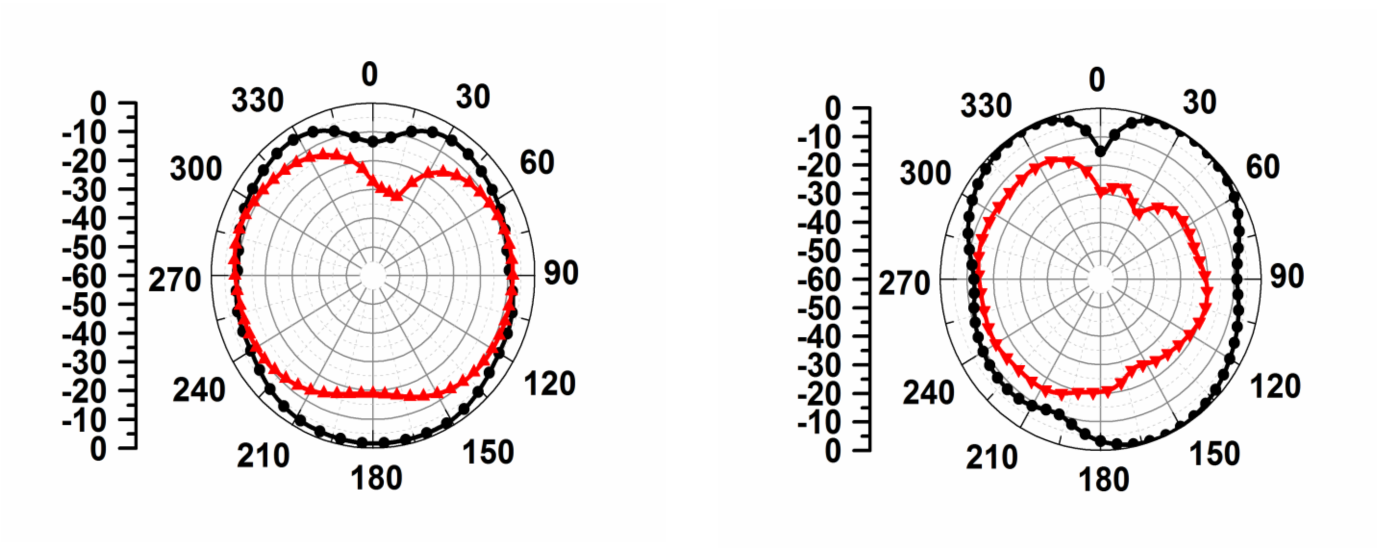


(b)

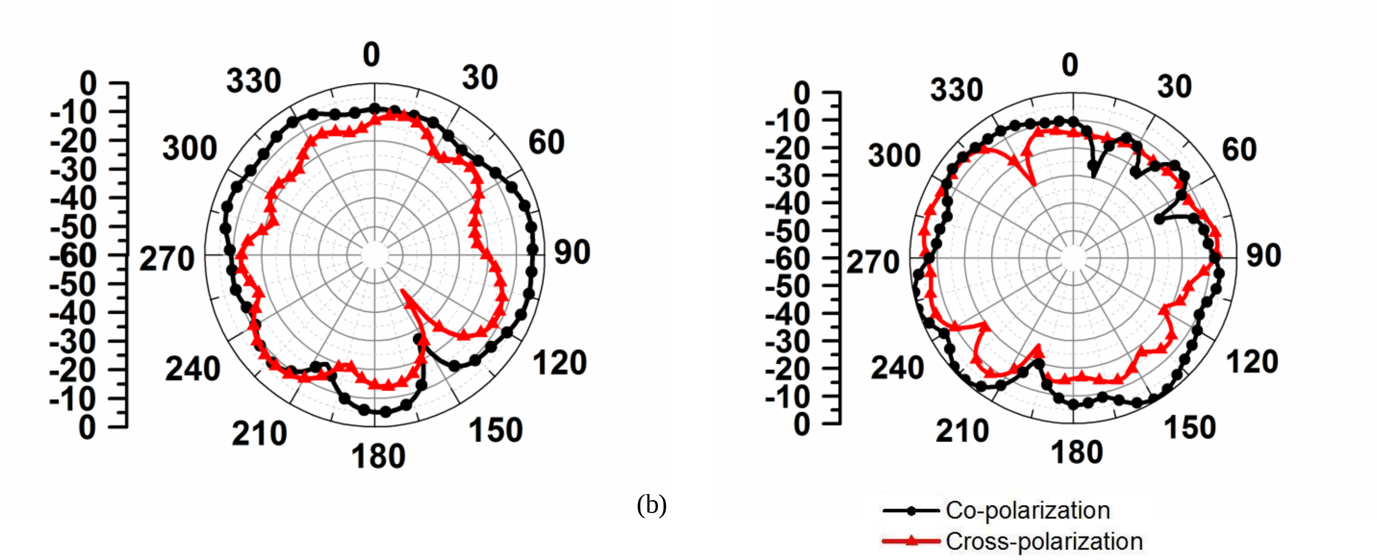
Fig. 6 Current distribution at a) 4.5 and b) 9.5 GHz

The gain as well as efficiency was effected by the lossy FR4 dielectrics materials that was used as a substrate materials. Using more high-priced microwave substrate compare to standard low value FR4, the gain and efficiency of the proposed patch antenna can be enhanced.

Fig. 6 has demonstrated the simulation results of current distribution of the proposed patch antenna for (a) 4.5 GHz, and (b) 9.5 GHz. It can be observed that feeding line carry large amount of current. In this point, electric field has been generated. Current distribution is more stable in lower band than in upper band. In upper band, the creation of electric field near slots is reasonable. Therefore, excitation is strong on both the upper band as well as the lower band in the entire parts of the antenna.



(a)



(b)

Fig. 7 Radiation pattern at a) 4.5 and b) 9.5 GHz

Fig. 7 has illustrated the radiation pattern of proposed patch printed antenna with measurement. Moreover, in Fig. 7 for (a) and (b) 4.5 GHz at E-plane and H- plane, respectively, (c) and (d) 9.5 GHz at E-plane, and H-plane simultaneously. The co-polarization and cross-polarization have been indicated by E_{θ} and $E_{\emptyset}$, respectively. In radiation pattern, the cross-polarization is lower in the E-plane of microstrip antenna. The effect of cross-polarization is higher in the H-plane for both resonances. The effect increases interpreting from the radiation pattern easily when frequency increases. In addition, symmetrical and around omnidirectional radiation patterns have been achieved along both H-plane and E-plane.

IV. CONCLUSIONS

A better performance UWB line-fed printed monopole antenna having a total dimension of 3.5 cm × 2.4 cm has been successfully implemented on a low-priced FR4 substrate and discussed in this paper. The measurement result demonstrates the proposed patch antenna can attain a bandwidth of 3.1-12.3 GHz for VSWR≤2. The measured and simulation results also shown excellent performance in terms of antenna gain, steady omnidirectional radiation patterns, reflection co-efficient, and short profile. Finally, because of its compact size, simple shape and well performance. The proposed antenna be attractive for use fortune UWB wireless systems.

REFERENCES

[1] H. G. Schantz, "UWB magnetic antennas," in *Proc. IEEE Antennas Propag. Soc. Int. Symp.,* USA, 2003, pp. 604-607.

[2] A. Singh, J. A. Ansari, Kamakshi, M. Aneesh, S. S. Sayeed, " Analysis of slot loaded compact antennas for dualband operation" International Journal of Applied Eletromagnetics and Mechanics, vol. 47, no. 1, pp. 163-175, 2015.

[3] C. M. Peng, I-F. Chen, C. C. Hung, Z. Hao, "Dual cross-shaped shorted-slots loaded patch antenna for WLAN applications" International Journal of Applied Eletromagnetics and Mechanics, vol. Preprint, no. Preprint, pp. 1-8, 2015.

[4] M. M. Islam, M. T. Islam and M. R. I. Faruque, "Design of an UWB Patch Antenna for Dual Frequency Operations", *Research Journal of Applied Sciences, Engineering and Technology*, vol. 7, Issue no. 4, pp. 822-825, Jan. 2014.

[5] Y. J. Ren, and K. Chang, "ultra-wideband planar elliptical ring antenna", *Electron Lett.* vol. 42, no. 8, pp. 447-449, May. 2006.

[6] J. Liang, C. C. Chiau, X. Chen, and C. G. Parini, "Study of a printed circular disc monopole antenna for UWB systems," *IEEE Trans. Antenna Propag.* vol. 53, no. 11, pp. 3500-3504, Nov. 2005.

[7] N. C. Azenui, and H. Y. D. Yang, "A printed crescent patch antenna for ultrawideband applications", *IEEE Antenna Wirel. Propag.Lett.* vol. 6, pp. 113-116, Apr. 2007.

[8] C. B. Kim, J. S. Lim, J. S. Jang, Y. H. Jung, H. S. Lee, and M. S. Lee, " Wideband notched compact UWB antenna", International Journal of Applied Eletromagnetics and Mechanics, vol. 28, no. 1,2, pp. 101-110, 2008.

[9] R. Azim, M. T. Islam, and N. Misran, "Microstrip Line-fed Printed Planar Monopole Antenna for UWB Applications", *Arab J Sci Eng*, vol. 38, no. 9, pp. 2415-2422, Sep. 2013.

[10] M. M. Islam, M. T. Islam and M. R. I. Faruque, "Dual-band operation of a microstrip patch antenna on a Duroid 5870 substrate for Ku- and K-bands," The Scientific World Journal, vol. 2013, pp. 10 pages, Nov. 2013.